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ABSTRACT

This research study evaluated the effects of memory demand on sustained attention, by varying the time interval between the presentations of stimuli in a cognitive vigilance task. Sixteen retarded and 16 nonretarded adult observers performed four 60-minute visual vigilance tasks in which single digits were presented sequentially and successively at either a high rate (30 events per minute) or a low rate (15 events per minute). During two of the four tests, the event rate presented during the initial 30 minutes was shifted without warning to the alternate event rate for the final 30 minutes. Results of the study indicated the presence of a vigilance decrement in the performance of retarded observers during both event rate conditions. Retarded adults detected fewer targets and made many more false alarm responses than did nonretarded adults. It is concluded that educational programs need to be aware that adults with mental retardation attend to crucial information less often than the nonretarded, and they tend to make more false positive responses. (JDD)

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The Effects of a Shift in Background Event Rate on the Vigilance Performance of the Mentally Retarded

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Abstract

The present research evaluated the effects of memory demand through stimuli presentation rate on the vigilance performance of mentally retarded and nonretarded adult observers. Retarded and nonretarded adult observers performed four 60-min visual vigilance tasks in which single digits were presented sequentially and successively at either a high rate (30 events per minute) or at a low rate (15 events per minute). The target events in all tests were skipped digits. During two tests, the event rate presented during the initial 30 minutes was shifted without warning to the alternate event rate for the final 30 minutes of the vigil. The results of the study indicated the presence of a vigilance decrement in the performance of retarded observers during both event rate conditions. Retarded adults detected fewer targets and made many more false alarm responses than did nonretarded adults. Also, the false alarm responses of retarded observers were related to the shift in background event rate. Vigilance performance of retarded adults is believed to be influenced by memory demands present in vigilance tasks. Observation of the performance of retarded individuals on vigilance tasks which require monitoring of successively presented stimuli has important practical applications for the education and training of the retarded.

THE EFFECTS OF A SHIFT IN BACKGROUND EVENT RATE ON THE VIGILANCE PERFORMANCE OF THE MENTALLY RETARDED

The ability of observers to focus awareness on stimuli over extended, uninterrupted time periods is measured in vigilance research. The present study was designed to evaluate vigilance performance in terms of an information-processing theory of sustained attention proposed by Parasuraman (Davies & Parasuraman, 1982; Parasuraman, 1979) which predicts that memory requirements inherent in certain types of vigilance tasks are related to sustained attention and the vigilance decrement.

Davies and Parasuraman (1982) developed a taxonomy of vigilance performance based upon a review of 27 studies and their own research. They predict that vigilance behavior will be affected by three interacting factors: (a) signal discrimination demands, (b) signal complexity, and (c) event rate. Vigilance performance differs on tasks which require observers to make simultaneous as opposed to successive discriminations between or among stimuli (Davies & Parasuraman, 1982; Parasuraman, 1979, 1984; Parasuraman & Davies, 1977). One explanation for the difference in performance is that when stimuli are presented successively, memory demands are placed on the observer. When stimuli are presented simultaneously, no memory demands are placed on the observer (Davies & Parasuraman, 1982).

In the typical vigilance task, sensory stimuli such as lights and tones serve as background events (nontarget events) and critical events (target events). Stimuli are presented at near-threshold or just noticeable levels. The observer is required to make judgments based upon differences in physical characteristics of stimuli such as size, intensity, or duration. Tasks that employ stimuli presented at near-threshold levels place perceptual demands upon observers and are referred to as "sensory" vigilance tasks (Davies &

Parasuraman, 1982). Vigilance tasks which employ symbolic stimuli such as alphabetical letters or digits that are presented for inspection at levels well above threshold are referred to as "cognitive" vigilance tasks (Davies & Parasuraman, 1982).

Relatively little systematic evaluation has been made of the performance of observers on cognitive vigilance tasks. However, there is reason to believe that the factors which influence performance on cognitive-type tasks may differ fundamentally from those affecting performance on sensory-type tasks. For example, the vigilance decrement does not appear during some cognitive vigilance tasks; rather, vigilance increments have been observed during prolonged vigils in some cases (Lysaght, Warm, Dember, & Loeb, 1984; Warm, Fishbein, Howe, & Kindell, 1976, cited in Warm & Jerison, 1984; Warm, Sprague, & Dember, 1981, cited in Warm & Jerison, 1984).

Monitoring efficiency is also influenced by the rate at which stimuli are presented to observers during a vigilance task. The event rate has been found to be a potent determinant of the vigilance decrement (Guralnick, 1973; Jerison, 1967; Jerison & Pickett, 1964; Johnston, Howell, & Goldstein, 1966; J. Mackworth, 1965b; Parasuraman, 1979; Parasuraman & Davies, 1976). Of particular importance is the frequency of background or nontarget events during a vigil. According to the taxonomy of Davies and Parasuraman (1982), event rates which present 24 or more events per minute are considered "high" and event rates which present less than 24 events per minute are considered "low". Studies which evaluated sustained attention with experimental paradigms that employ sensory stimuli have observed an inverse relation between event rate and detection of critical signals when the probability of target events is equated within event rates (Jerison, 1965, 1967, 1970; Loeb & Binford, 1968; J. Mackworth, 1968; Parasuraman, 1979; Taub & Osborne, 1968) and when the probability is not equated (Guralnick, 1973; Jerison & Pickett,

1964; Jerison, Pickett, & Stenson, 1965; J. Mackworth, 1965a, 1965b; Parasuraman & Davies, 1976). Significantly more correct detections of critical signals occur when the presentation rate of simple sensory stimuli is low; whereas, a significant decrease in target detections is observed when the event rate is high (Guralnick, 1973; Jerison, Pickett, & Stenson, 1965; J. Mackworth 1965a, 1965b; Parasuraman & Davies, 1976).

While several studies (e.g., Krulewitz, Warm, & Wohl, 1975; Warm, Howe, Fishbein, Dember, & Sprague, 1984) have evaluated the effects of event rate on sustained attention, none has directly addressed the memory-load hypothesis of Parasuraman (1979). The purpose of the present study was to evaluate the effects of event rate on a cognitive-type task that placed memory demands upon observers. The hypothesis that the memory ability of observers would play a key role in the performance of successive-type vigilance tasks prompted an evaluation of vigilance performance of mentally retarded and nonretarded adults. It is well documented that retarded individuals have poorer memory abilities than nonretarded individuals. Studies measuring vigilance behavior in the mentally retarded have failed to find differences in performance as a function of intelligence using sensory tasks (Kirby, Nettlebeck, & Bullock, 1978; Ware, Baker, & Sipowicz, 1962). However, Tomporowski and Allison (in press) found a relation between intelligence and vigilance performance on a cognitive task. Also, it has been hypothesized that retarded individuals, because of their limited attentional capacities, will perform more poorly on discrimination tasks when the rate of stimulus presentation is high than when it is low (Nugent & Mosley, 1987).

The present research evaluated the effects of memory demand on sustained attention. Memory demand was manipulated by varying the time interval between the presentations of stimuli in a cognitive vigilance task. It was hypothesized that the ISI would be related to sustained attention: the longer ISI would produce poorer performance in observers due to the extended

time that information would be held in memory. The longer ISI conditions were hypothesized to have a greater debilitating effect on the signal detection of retarded than nonretarded observers due to the deficit memory abilities of retarded persons (Baumeister, Hawkins, & Holland, 1967; Hawkins & Baumeister, 1965, cited in Maisto & Baumeister, 1984). The study provides a direct test of Parasuraman's (1979) memory-load hypothesis and the vigilance task taxonomy of Davies and Parasuraman (1982) which predicts that target detection and perceptual sensitivity will decline during a vigil under conditions in which stimuli are presented successively at a high rate; whereas, no decline in perceptual sensitivity will occur under the low event rate condition. It was expected that the overall percentage of critical signals detected in this study would be inversely related to the rate of presentation of background events. A shift in background event rate from high to low was predicted to produce an improvement in monitoring efficiency while a shift in event rate from low to high was predicted to produce a decrement in monitoring efficiency.

Method

Subjects

Thirty-two adults participated in the study. Sixteen individuals recruited from a regional educational program sponsored by a community association for retarded citizens comprised the mentally retarded (MR) group (6 males and 10 females; MCA = 28.93 years; SDA = 4.89 years; Range = 23-42 years). Scores on intelligence tests were available for all 16 participants in the MR group (MIQ = 64.75; SDIQ = 5.71; Range = 56-79 in IQ scores). Thirteen of the subjects in the MR group were diagnosed as cultural-familial retarded and three subjects were diagnosed as Down's syndrome. Subjects in the MR group were paid $5.00 for each of four test sessions. Sixteen students recruited from introductory psychology courses at The University of Alabama comprised the nonmentally retarded (NMR) group (8 males and 8 females; MCA = 18.69; SDA = .79 years; Range = 18-20 years). Subjects in the NMR group received extra course credit for their participation. All subjects in each group were advised

that they could withdraw from the study without penalty.

Procedure

Four 60-min vigilance tasks were individually administered to each subject at the same time of day on separate days within a 7-day period. The order of testing was counterbalanced (D'Amato, 1970, p. 56). Each vigilance test was a counting task in which digits, 3.0 cm in height, were presented serially and repetitively from 1 to 9. The target to be detected was a missing digit in a set (e.g., 1, 2, 3, *5, 6, 7, 8, 9...) while all other digits constituted background events.

Each of the four test sessions consisted of two 3-min practice periods and a 60-min vigilance test period. At the beginning of each test session, a set of written instructions appeared on the screen. The instructions were read aloud by the experimenter who was present throughout each test session. When subjects indicated that the instructions were understood, the first practice period began. The test required subjects to monitor a videoscreen and detect target events from background events. Stimuli were presented successively on a computer-controlled CRT. A trial was defined as the presentation of a target or background stimulus followed by an interval during which the CRT was blank. Subjects responded by pressing the space bar on the computer keyboard. A response was considered a "hit" if it occurred following the onset of a target event. Failure to respond following the onset of a target event constituted a "miss." A response following a background event constituted a "false alarm."

Each test was preceded by two practice periods. The practice periods were designed to ensure the subject's ability to perform the task. During the first practice period, there were 6 target events and 54 background events for a total of 60 events in the 3 min period. The stimulus duration was 1 s followed by a 2 s ISI. Verification of a subject's ability to discriminate target events from background events was obtained by calculating a measure of perceptual sensitivity, $P(\overline{A})$, a nonparametric measure of d' (Pollack & Norman, 1964). Subjects were required to attain a $P(\overline{A})$ score of ≥ 80 to begin each of the main tests.

For two of the conditions, the second practice test consisted of 5 target events and 85 background events for a total of 90 events in the 3-min period. The stimulus duration was 1 s and the ISI was 1 s. For the other two

conditions, the second practice test consisted of 5 target events and 40 background events for a total of 45 events in a 3 min period. In this practice test, the stimulus duration was 1 s and the ISI was 3 s. The second practice test was identical to the initial 30 min of the main task administered during that test session.

Observers completed four tests: two nonshift and two shift conditions. They received either a high or a low background event rate during the first half of the vigil (preshift phase) and then experienced either the same or the alternate background event rate during the final half (postshift phase). The four vigilance tests were high-high (HH), high-low (HL), low-low (LL), and low-high (LH).

During the main test, the high rate consisted of digit presentation for a duration of 1 s with an ISI of 1 s for a total of 30 presentations per min. The low rate consisted of digit presentation for a duration of 1 s with an ISI of 3 s for a total of 15 presentations per minute. Fifteen critical signals for detection were presented in each of the six 10-min time blocks for a total of 90 critical signals to be detected per test. The high rate of presentation included 285 nontargets per 10-min time block and the low rate included 135 nontargets per time block. The number of false alarms made divided by the number of nontargets presented produced the proportion of false alarms per 10-min time block. Measures of each subject's hit rate, false alarm responses, and perceptual sensitivity were calculated for six successive 10-min periods of each vigilance test.

In the shifted conditions, the change occurred after 30 minutes of the task. The new rate lasted for the final half of the test. The vigil proceeded from preshift to postshift phases without interruption and, except for changes in event rate, there was no discernible difference between periods. Subjects in the shifted conditions were not instructed about a possible change in event rates. For the nonshifted control conditions, the background event rate remained constant throughout the vigil.

Results

The mean numbers of target detections, false alarm responses, and perceptual sensitivity scores differed considerably between nonretarded and retarded observers. The performance of the nonretarded observers show ceiling effects for target detections and perceptual sensitivity scores and a floor

effect resulting from few errors of commission. Due to the ceiling and floor effects of these measures, nonparametric statistical comparisons via Friedman Analysis of Variance by Ranks (Siegel, 1956) between the two groups of observers were made. An inspection of the mean numbers of target detections for both groups of observers presented in Figure 1 reveals the inferior performance of the retarded observers [X^2 (5) = 30.51, $p < .001$]. Likewise, Figure 2 reveals that greater numbers of false alarms were committed by the retarded observers during the vigils [X^2 (5) = 27.28, $p < .05$] . Figure 3 provides the average perceptual sensitivity, $P(\overline{A})$. Inspection of $P(\overline{A})$ scores of retarded and nonretarded observers during the four test conditions reveals marked differences in the performance of mentally retarded and nonretarded observers [X^2 (5) = 29.55, $p < .001$].

Analyses of target detections, false alarm responses, and perceptual sensitivity scores of the mentally retarded observers were conducted separately. Each measure was evaluated with three repeated-measures ANOVAs. The first analysis evaluated performance of observers on the four tests during the 30-min preshift phase. An analysis was also conducted that compared subjects' collapsed performance across tests in which the same event rate of high or low was experienced. The second analysis assessed performance of subjects during the two test conditions in which the background event rate remained constant (either high or low) throughout the entire 60-min test. The third analysis evaluated the effects of shifts in background event rate on vigilance performance by comparing performance during the third preshift time block with postshift performance during the final 30 min of the time on task.

Analyses of target detections, false alarm responses, and $P(\overline{A})$ scores of the nonretarded observers were conducted separately. Each measure was evaluated with three Friedman Analysis of Variance by Ranks (Siegel, 1956). The first analysis evaluated the performance of observers during the initial 30 min of each of the four tests. The second analysis evaluated the performance of observers collapsed across tests in which the same event rate of high or low was experienced for the first 30 min. The third analysis evaluated performance of observers across the entire 60-min vigil.

Target detection

Mentally retarded observers. During the initial 30 min of the vigil, the

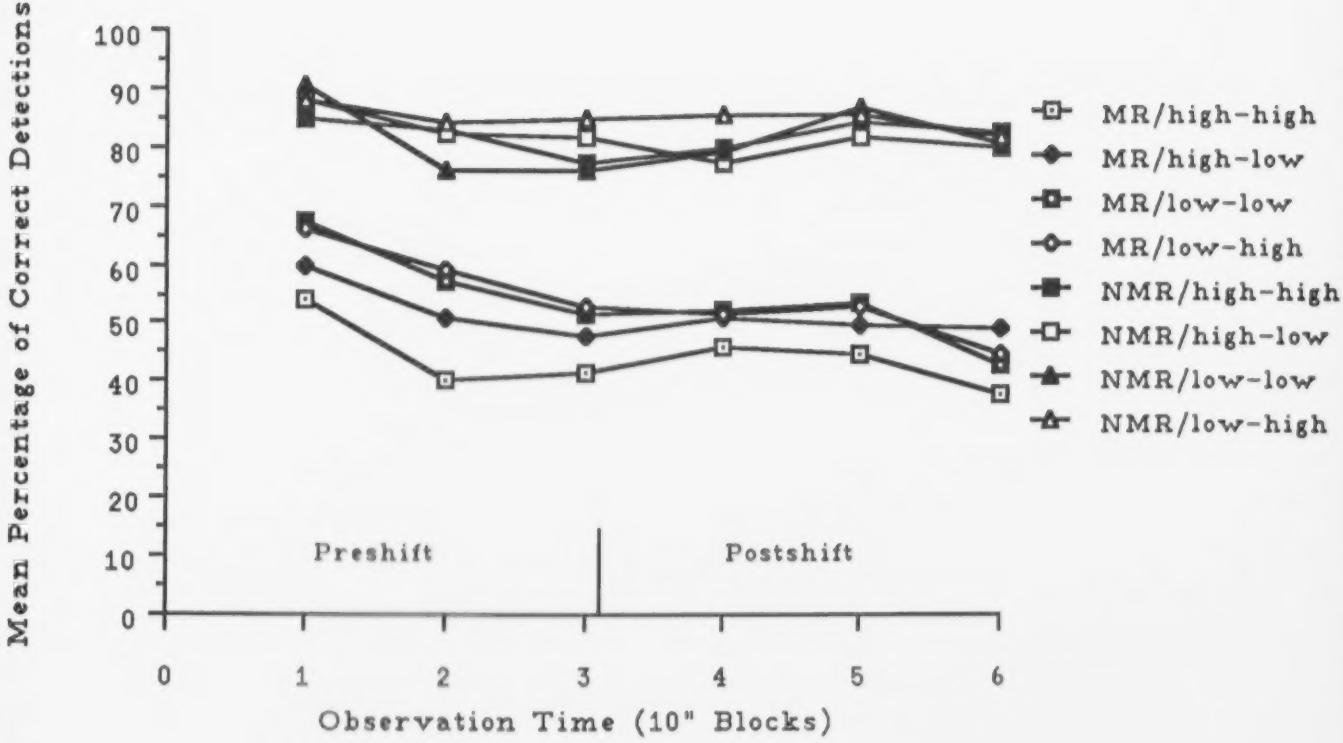

Figure 1. Percentage of Correct Detections.

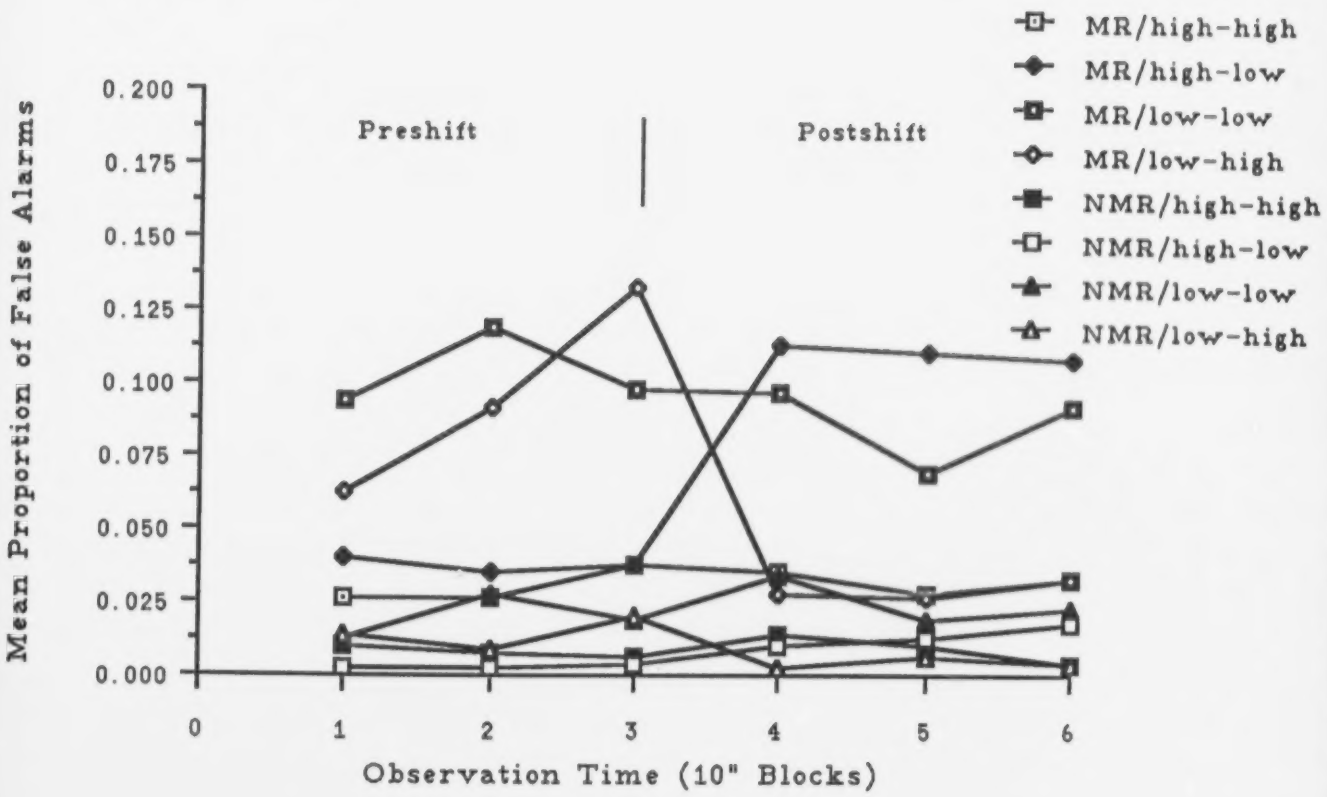

Figure 2. Proportion of False Alarms.

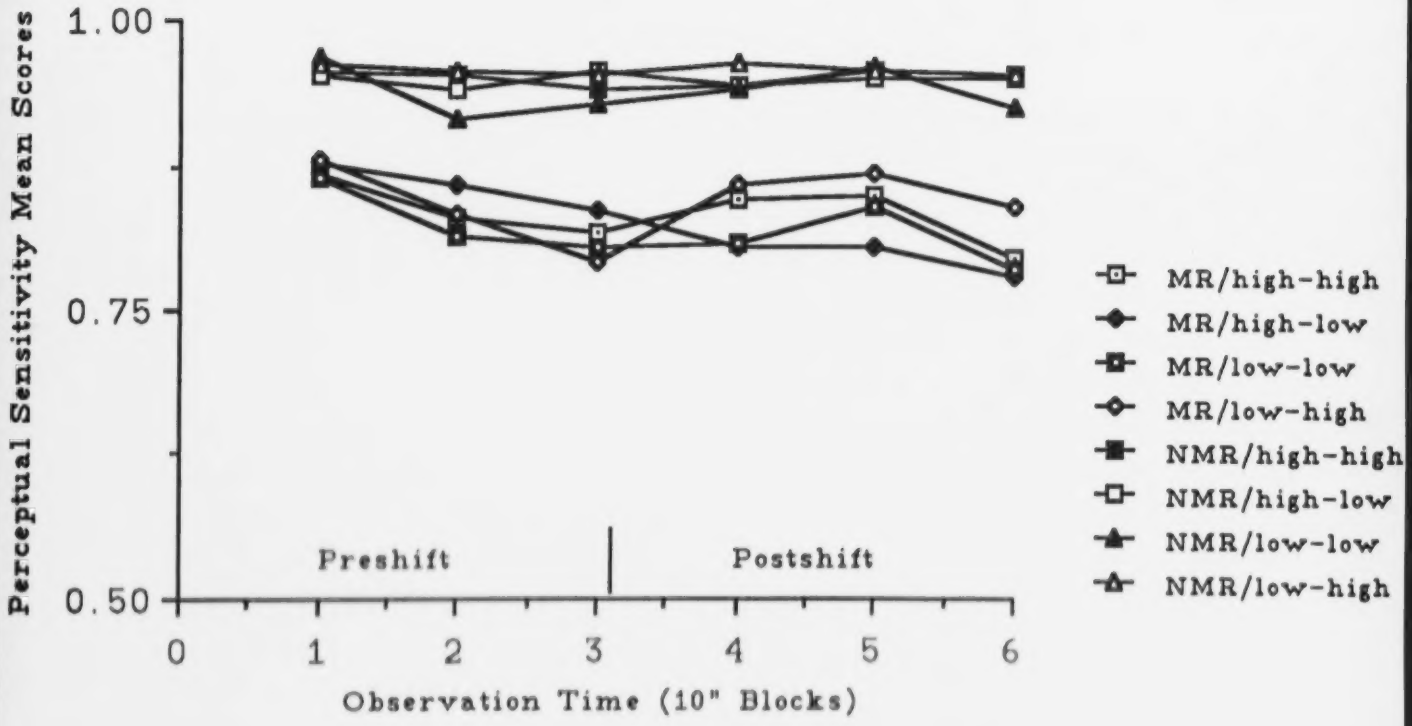

Figure 3. Perceptual Sensitivity Scores.

mean number of targets detected declined significantly [F (2, 30) = 10.72, $p < .001$] and there was a significant difference among the four test conditions [F (3, 45) = 3.93, $p < .01$] with no significant test by time period interaction [F (6, 90) = .51, $p > .05$]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate, there was no significant difference between the performance of subjects as a function of event rate [F (1, 30) = 1.63, $p > .05$]. There was a significant decrement in the number of target detections [F (2, 60) = 13.75, $p < .0001$] with no interaction between tests and time [F (2, 60) = .51, $p > .05$]. Performance under the two nonshifted tests in which observers experienced high or low event rates throughout the entire 60-min vigil differed significantly [F (1, 15) = 13.60, $p < .01$] and a significant decline in performance during the vigil [F (5, 75) = 6.34, $p < .001$] with no interaction between test and time period [F (5, 75) = .80, $p > .05$]. An analysis of target detections at each time period revealed the nonshifted high event rate test produced significantly fewer detections during the first three periods of watch [period 1: t(15) = 2.45, $p < .05$; period 2: t(15) = 3.05, $p < .01$; period 3: t(15) = 2.74, $p < .05$]. Performance did not differ significantly between the nonshifted groups during the final three periods of the vigil [period 4: t(15) = .95, $p > .05$; period 5: t(15) = 1.86, $p > .05$; period 6: t(15) = .87, $p > .05$].

An analysis comparing target detections during the preshift time block, or third period of watch, with postshift performance during the final 30 min of the time on task revealed that the shift in background event rate did not significantly affect target detection in any of tests [F (3,45) = 1.62, $p > .05$]. Further, the rate of detection did not decline significantly during the final 40 min of the vigil [F (3,45) = 1.62, $p > .05$] and there was no statistical interaction between test and period of time [F (9, 135) = .57, $p > .05$].

Nonretarded observers. There was a significant decrement in target detection during the initial 30 min of the vigil for the nonshifted low event rate only [X^2 (2) = 9.88, $p < .01$]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate, there was no significant decrement in performance of subjects under the high event rate during the preshift phase [X^2 (2) = 4.16, $p > .05$]. There was a significant decrement in performance of subjects under the low event rate during the preshift phase [X^2 (2) = 8.53, $p < .05$]. Separate analyses of the

four tests across the entire 60-min vigil determined no significant change in target detection over time [HH: X^2 (2) = 4.61, $p > .05$; HL: X^2 (2) = 7.79, $p > .05$; LL: X^2 (2) = 10.32, $p > .05$; LH: X^2 (2) = 4.11, $p > .05$]. Also, there were no significant differences among the four test conditions at any of the six periods of the vigil [period 1: X^2 (3) = 1.18, $p > .05$; period 2: X^2 (3) = 3.47, $p > .05$; period 3: X^2 (3) =.43, $p > .05$ period 4: X^2 (3) = 4.07, $p > .05$; period 5: X^2 (3) = 1.63, $p > .05$; period 6: X^2 (3) = .43, $p > .05$].

False alarm responses

Mentally retarded observers. The proportion of false alarm responses made during the initial 30 min of the vigil differed significantly among the four tests [F (3, 45) = 5.62, $p < .01$]. There was no significant change in the frequency of false alarms during the preshift periods across time [F (2, 45) = 2.33, $p > .05$] and no significant interaction between test conditions and time periods [F (6, 90) = 1.85, $p > .05$]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate, there was a significant difference between the two event rate conditions [F (1, 30) = 8.73, $p < .01$], with no significant change in performance across the first three time periods [F (2, 60) = 1.96, $p > .05$] and no significant interaction between test conditions and time periods [F (2, 60) = 1.50, $p > .05$]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate, there was a significant difference between groups at each of the initial three time periods [period 1: (t (15) = 2.35, $p < .05$; period 2: t (15) = 3.38, $p < .01$; period 3: t (15) = 3.28, $p < .01$].

Performance under the two nonshift conditions in which subjects experienced a high or low background event rate throughout the entire 60-min vigil differed significantly [F (1, 15) = 9.99, $p < .01$]. A series of t-tests revealed that the separation in performance under the two event rates was significant at the last five time periods and was marginally significant at the first block of time [period 1: t (15) = 2.06, p =.0577; period 2: t (15) = 2.89, $p < .05$; period 3: t (15) = 2.17, $p < .05$; period 4: t (15) = 2.57, $p < .05$; period 5: t (15) = 2.13, $p < .05$; period 6: t (15) = 3.31, $p < .01$]. There was no change in performance across the six blocks of time [F (5, 15) = .77, $p > .05$] and no interaction between test conditions and time periods [F (5,75) = .85, $p > .05$].

False alarm responses during the final 40 min of a vigil were

significantly affected by changes in background event rate. These changes resulted in a significant main effect for test conditions [F (3, 45) = 4.09, p < .02], no main effect for time period [F (3, 45) = 1.38, p > .05], and a significant test condition by time period interaction [F (9, 135) = 7.02, p < .001]. Analyses of false alarm responding during the last 10 min of the preshift phase and the first 10-min period of the postshift period revealed that under the condition where the event rate shifted from a high rate to a low rate, there was a significant increase in the number of false alarm responses made [t (15) = 2.59, p < .05] and under the condition where there was a shift from a low rate to a high rate, there was a significant decrease in the number of false alarm responses made [t (15) = 3.68, p < .01]. Individual ANOVAs were performed on the percentage of false alarm responses made on the four test conditions during each 10-min period of the postshift phase and they yielded significant differences at each period [period 4: F (3, 45) = 5.83, p < .01; period 5: F (3, 45) = 5.42, p < .01; period 6: F (3, 45) = 5.20, p < .01]. Post hoc comparisons using the Bonferroni method of multiple comparisons revealed that the performance of subjects under the two high event rate conditions did not differ at any of the postshift time periods [period 4: t(.996, 45) = 2.971, p > .05; period 5: t(.996, 45) = 2.971, p > .05; period 6: t(.996, 45) = 2.971, p > .05] and the performance of subjects under the two low event rate conditions did not differ at any of the postshift time periods [period 4: t(.996, 45) = 2.971, p > .05; period 5: t(.996, 45) = 2.971, p > .05; period 6: t(.996, 45) = 2.971, p > .05]. The performance of subjects experiencing a shift from high to low event rate, differed significantly from the performance of subjects experiencing a shift from low to high event rate at each time period of the postshift phase of the vigil [period 4: t (.996, 45) = 2.971, p < .05; period 5: t(.996, 45) = 2.971, p > .05; period 6: t(.996, 45) = 2.971, p > .05].

Nonretarded observers. The results of an analysis of the proportion of false alarm responses made during the initial 30 min of each test condition reflect that none of the four conditions yielded a significant change in the frequency of false alarms during the preshift periods across time [HH: X^2 (2) = .22, p > .05; HL: X^2 (2) = 2.34, p > .05; LL: X^2 (2) = 2.63, p > .05; LH: X^2 (2) = 5.91, p > .05]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate, there was a significant decrement in performance under the low event rate only [high rate:

X^2 (2) = 1.97, $p > .05$; low rate: X^2 (2) = 6.59, $p < .05$]. The only test in which false alarm responses made during the entire 60-min vigil yielded a significant difference was the shifted low-to-high event rate test condition [HH: X^2 (5) = 1.99, $p > .05$; HL: X^2 (5) = 7.24, $p > .05$; LL: X^2 (5) = 4.31, $p > .05$; LH: X^2 (5) = 17.28, $p < .01$]. The decrease in errors of commission were due to the shift from low to high in event rate. Individual analyses were performed on the percentage of false alarm responses made on the four test conditions during each 10-min period of the postshift phase and they yeilded significant differences only at the third period [period 1: X^2 (3) = 1.22, $p > .05$; period 2: X^2 (3) = 2.91, $p > .05$; period 3: X^2 (3) = 9.28, $p < .05$ period 4: X^2 (3) = 2.87, $p > .05$; period 5: X^2 (3) = 1.54, $p > .05$; period 6: X^2 (3) = 2.83, $p > .05$].

Signal detection analysis

Mentally retarded observers. An analysis of sensitivity scores of retarded observers among the four test conditions during the 30-min preshift phase revealed a significant decline in sensitivity over the three blocks of time for all tests [F (2, 30) = 8.19, $p < .01$]. There were no significant differences among the four test conditions [F (3, 45) = .56, $p > .05$] and no significant interaction between test condition and time period [F (6, 90) = .71, $p > .05$]. When the performance of subjects was collapsed across tests in which subjects experienced a high or low background event rate for the first 30 min of the vigil, there was no significant difference between the two event rate conditions [F (1, 30) = .29, $p > .05$]; however, a significant decline in sensitivity was detected [F (2,60) = 9.57, $p < .001$] with no significant interaction between test condition and time period [F (2, 60) = .65, $p > .05$].

Performance under the two nonshifted tests in which observers experienced a high or low event rate throughout the entire 60-min vigil did not differ significantly [F (1, 15) = .54, $p > .05$]; however, there was a significant decline in perceptual sensitivity during the vigil [F (5, 75) = 3.19, $p < .05$] with no interaction between test and time period [F (5, 75) = .24, $p > .05$].

The assessment of the sensitivity scores of observers during the final 40 min of the vigil revealed no significant main effect for test condition [F (3, 45) = 1.17, $p > .05$], a marginally significant decrement in performance over time [F (3, 45) = 2.74, $p < .06$], and a marginally significant test condition by time period interaction [F (9, 135) = 1.92, $p < .06$] suggesting that performance was influenced

by the shift in event rate. Analyses of the change in sensitivity from the third time block (preshift phase) to the fourth time block (postshift phase) revealed that under the test condition in which the event rate shifted from a low rate to a high rate perceptual sensitivity increased significantly [t (15) = 2.99, $p < .01$]; however, a shift from a high rate of presentation to a low rate did not significantly influence sensitivity [t (15) = 1.20, $p > .05$]. Individual ANOVAs were performed on the percentage of false alarm responses made on the four test conditions during each 10-min period of the postshift phase and they yeilded significant differences at only the fifth time period [period 4: F (3, 45) = 2.09, $p > .05$; period 5: F (3, 45) = 2.75, $p < .05$; period 6: F (3, 45) = 2.09, $p > .05$]. A post hoc comparison using the Bonferroni method of multiple comparisons revealed that performance of subjects under the two high event rate conditions did not differ at the fifth time period [t (.996, 45) = 2.97, $p > .05$] and the performance of subjects under the two low event rate conditions did not differ at the fifth time period [t (.996, 45) = 2.97, $p > .05$]. The perceptual sensitivity of subjects under the two shifted event rate test conditions differed significantly at the fifth block of time [t (.996, 45) = 2.97, $p < .05$] showing greater sensitivity to critical stimuli after being shifted from the low to the high event rate.

Nonretarded observers. An analysis of sensitivity scores among the four test conditions during the initial 30 min, or preshift phase, revealed a significant decline in sensitivity over the three blocks of time for the nonshifted low event rate (LL) test condition only [HH: X^2 (2) = 4.59, $p > .05$; HL: X^2 (2) = 2.09, $p > .05$; LL: X^2 (2) = 11.63, $p < .01$; LH: X^2 (2) = 4.16, $p > .05$]. When the perceptual sensitivity scores of subjects were collapsed across tests in which subjects experienced a high or low background event rate, there was no significant decrement in performance of subjects under the high event rate [X^2 (2) = 3.41, $p > .05$]. There was a significant decrement in perceptual sensitivity under the low event rate [X^2 (2) = 9.41, $p < .01$]. An analysis of sensitivity scores among the four test conditions during the entire 60-min vigil revealed a significant decline in sensitivity over the six blocks of time in the nonshifted low event rate condition only [HH: X^2 (5) = 4.79, $p > .05$; HL: X^2 (5) = 5.24, $p > .05$; LL: X^2 (5) = 12.20, $p < .05$; LH: X^2 (5) = 8.30, $p > .05$]. Individual analyses which were performed on the perceptual sensitivity scores of each period yielded no significant differences among the four test conditions at any of the six periods

[period 1: X^2 (3) = 1.31, $p > .05$; period 2: X^2 (3) = 1.71, $p > .05$; period 3: X^2 (3) = .51, $p > .05$ period 4: X^2 (3) = 1.97, $p > .05$; period 5: X^2 (3) = 4.56, $p > .05$; period 6: X^2 (3) = .22, $p > .05$].

Discussion

The vigilance performance of the mentally retarded differed significantly from the performance of nonretarded observers in terms of target detection, errors of commission, and perceptual sensitivity in the present study. Mentally retarded observers detected fewer critical signals, made many more false alarm responses, and exhibited less sensitivity to stimuli than the nonretarded observers. These findings differ from Kirby et al. (1978) and Ware et al. (1962) who failed to find differences in vigilance behavior as a function of intelligence level and supports the finding of Tomporowski and Allison (in press) that there is a relation between intelligence and vigilance performance.

The effects of two background event rates on sustained attention during the initial 30 min of a 60-min vigil and the effects of shifts in background event rate on sustained attention during the final 30 min of a vigil were assessed for both groups of observers. During the 30-min preshift period of each test, the mean number of targets detected by retarded and nonretarded observers declined significantly. There was, however, no difference in target detection as a function of background event rate. This finding differs from previous studies which evaluated the effects of background event rate on target detection employing sensory-type tasks (Guralnick, 1973; Jerison, Pickett, & Stenson, 1965; Krulewitz et al.,1975; J. Mackworth, 1965; Parasuraman & Davies, 1976). The results of the present study and other cognitive-type tasks (Lysaght, Warm. Dember, & Loeb, 1984; Warm et al., 1976, cited in Warm, 1984; Warm et al., 1981, cited in Warm, 1984) support the general task taxonomy of Davies and Parasuraman (1982) which proposes that vigilance performance is a complex phenomenon that is related to such task demands as signal discrimination demands, signal complexity, and rate of stimulus presentation.

Previous studies have obtained evidence that target detection is influenced by unsignalled shifts in event rate (Krulewitz, Warm, & Wohl, 1975). However, in the present study the shifts in background event rate did not affect target detection of either mentally retarded or nonretarded observers. The failure of the present study to detect differences in target detections as a

function of a shift in background event rate may be because the high and low event rates did not produce significant differences in the target detection performance of observers in the preshift phase. Under these conditions, changes in event rate would not be expected to exert much influence on target detection. Also, methodological differences may be responsible for the lack of correspondence with past findings. Krulewitz et al. (1975) employed a simple sensory-type vigilance procedure that required college students to perform a simultaneous discrimination task; whereas, the present study employed a cognitive-type task that required college students and mentally retarded adults to perform a successive discrimination task.

An evaluation of false alarm responses of the mentally retarded during the preshift period of the vigil revealed that the frequency of errors of commission made was a function of background event rate. The length of the ISI produced significant differences in the percentage of false alarms made, with more errors committed under the longer delay condition. The average proportion of false alarm responses made by the mentally retarded observers during the 30-min period under the high presentation rate was 3.38 %; however, when stimuli were presented at a low rate, the average proportion of false alarms across the 30-min period was 9.96 %. These differences in performance as a function of background event rate did not exist for the nonretarded observers. The mean number of false alarms made by mentally retarded and nonretarded observers did not decline significantly during the preshift phase; further, under nonshift conditions, the proportion of false alarms did not change during the entire 60-min vigil. The observation that the frequency of false alarms did not decrease during the vigil is intriguing. Under conditions in which sensory-type tasks are used, false alarm rates tend to decline as a function of time on vigil. The decline in false alarm responses has been proposed to be due to a process in which the observer becomes more cautious about reporting a target with time (Broadbent & Gregory, 1963). In the present study, only hit rate of the mentally retarded and nonretarded observers declined during the vigil. Clearly, additional research will be needed to determine if this finding is unique to mentally retarded observers or to cognitive-type vigilance tests in general.

An analysis of the effect of a shift in event rate on the frequency of false

alarm responses of the mentally retarded revealed that the shift in event rate from high to low produced a significant increase in false alarm responses and the shift from low to high produced a significant decrease in false alarm responses. For both shift conditions, the frequency of false alarm responses remained constant throughout the postshift phase. The observed change in the frequency of errors of commission following a shift in background event rate are difficult to explain with existing theories of vigilance behavior. According to a physiological arousal theory proposed by J. Mackworth (1968), any change in stimulus conditions is predicted to improve vigilance performance. However, the arousal explanation is not tenable due to the observation that the frequency of errors of commission declined when event rate was shifted from low to high. The high event rate would be predicted to be more attentional demanding than the low rate condition resulting in less efficient performance (i. e., more false alarms) during the high event rate. In fact, mentally retarded observers made fewer false alarms during the high event rate than during the low event rate. A motivational explanation (Krulewitz et al., 1975), predicts that vigilance performance following shifts in event rate changes due to expectancy modifications. This theory is not tenable because of the lack of an "overshoot" that characterizes experiments which evaluate sudden shifts in expectancies and the lack of a gradual decline in false alarms during the final 30 min of the vigil which would have been predicted if the shift in frequency of false alarm responding was motivational in nature. In the present study, false alarm rates remained constant during the postshift phase and did not differ from performance under the nonshift conditions.

An alternative explanation invokes information-processing characteristics of observers (Parasuraman, 1979). The difference in the frequency of false alarm responses of mentally retarded observers implicates the role of memory processes during vigilance tasks which require successive discriminations to be made between stimulus events. The task demanded successive discriminations to be made between stimulus events by requiring observers to remember the value of a digit and to compare that value to the next digit in the sequence. The high event rate required observers to remember the value of each presented digit for 1 s, whereas the low event rate required observers to remember the value of each digit for 3 s. Although the shift in

event rate from low to high produced a significant decrease in false alarms, it should be noted that the frequency of false alarms made by nonretarded observers was very low during both event rates. This finding conforms to the predictions of Warm et al. (1985) that cognitive-type tasks which present stimuli above threshold should yield only negligible errors of commission. It is believed that the frequency of false alarm responses made by mentally retarded observers reflect differences in memory abilities between retarded and nonretarded observers. The mentally retarded are characterized by poor STM and information-processing abilities (Baumeister et al., 1967; Ellis, 1963; Hawkins & Baumeister, 1965, cited in Maisto & Baumeister, 1984). The significantly greater number of false alarms committed under the low event rate supports the prediction that a memory load in the form of a longer ISI caused the poorer performance in the mentally retarded observers due to the time information had to be held in memory.

Traditionally, the study of vigilance behavior has focused on the evaluation of target detection; the analysis of false alarms has been given only secondary importance (Davies & Parasuraman, 1982). It was not until the introduction of Signal Detection Theory (SDT), which provides an analysis of both hits and false alarms (Green & Swets, 1966), that an interest in evaluating performance with respect to perceptual sensitivity (d') and criterion shifts (B) increased. Parasuraman and Davies' (1982) review and reanalysis of vigilance studies via SDT led them to predict that a decline in perceptual sensitivity would occur only when the observer is required to perform successive discriminations under a high event rate. In the present cognitive-type tasks, analysis of target detections and false alarm responses of mentally retarded observers using SDT revealed a significant decline in sensitivity over the 30-min preshift phase with no difference in sensitivity scores as a function of background event rate. These results provide support for Davies and Parasuraman's (1982) prediction that a decrement in sensitivity would be observed under conditions in which stimuli are presented successively. However, the prediction (Parasuraman, 1979) that a decrement in perceptual sensitivity will occur only when the event rate is high was not supported. Significant shifts in perceptual sensitivity occurred under both event rate conditions in this study. Further, a significant increase in sensitivity occurred

following a shift from low to high in background event rate.

The lack of correspondence between the predictions of Parasuraman (1979) and the data obtained in the present study may be resolved when the sensitivity scores obtained are viewed as measures of memory rather than measures of a perceptual process. Cognitive-type tasks present stimuli clearly above threshold; the studies reviewed by Davies and Parasuraman were primarily sensory-type vigilance tasks. As discussed by Norman and Bobrow (1975), the demands placed upon observers during near-threshold discrimination tasks differ fundamentally from those placed upon observers during above-threshold discrimination tasks. Performance on near-threshold tasks is dependent upon the quality of the signal presented as well as the sensory capabilities of the observer, therefore, discrimination is a function of the signal-to-noise ratio present in the task. Performance on above-threshold tasks is dependent upon the memory processes of the observer, therefore, improvement in discrimination can occur only by improving memory processes. A memory interpretation explains the false alarm responses made by the mentally retarded observers. False alarm responses were directly related to the delay interval between presentations of stimuli. The frequency of false alarms responses was a function of event rate and not a function of time on watch. The ISI required observers to retain information in memory and the length of the ISI determined performance. Recognizing the role of memory processes in a successive vigilance task, it is not surprising that measures of the sensitivity of the mentally retarded, who are considered to have memory deficits, decline over time.

It appears that the sustained attention of the mentally retarded is poorer than the nonretarded observers with respect to both target detection and errors of commission on the cognitive-type tasks employed in the present study. Mentally retarded observers responded to significantly fewer targets and made many more false alarms than nonretarded observers. These findings are of both theoretical and applied importance. Several theories have been proposed to explain the observation that mentally retarded individuals perform poorly on tests which demand attentional abilities. Das (1971) and others (Denny, 1966; Heal & Johnson, 1970; Krupski, 1977; Spitz, 1963) have proposed that poor performance of mentally retarded individuals on tests of attention is due to

their distractibility. The longer delay period between presentations of stimuli under the low event rate in the present study allowed a greater opportunity for distractors to compete with information in STM. The distractibility hypothesis may also explain the inferior target detection performance of the mentally retarded when compared to nonretarded observers. Previous research by Tomporowski and Allison (in press) obtained data which demonstrated that mentally retarded observers displayed significantly poorer performance than nonretarded observers in terms of target detections; however, the rate of the vigilance decrement during the vigil was similar for both groups. The distractibility hypothesis would posit that fewer targets were attended to by the mentally retarded; however, those targets attended to were processed in a fashion similar to the nonretarded.

The observation that mentally retarded individuals perform poorly on tasks of sustained attention which require monitoring of successively presented stimuli has important practical implications for the education and training of the mentally retarded. There are many daily tasks which require sustained attention and mentally retarded persons are often placed in work settings that demand vigilance abilities. The success or failure of the mentally retarded on these tasks may depend on the abilities of the individuals to meet the information-processing demands placed upon them. The present study provides evidence that the mentally retarded differ from the nonretarded in two important ways that may interfere with learning tasks and job performance. Mentally retarded observers attend to crucial information less often than the nonretarded and the retarded tend to make more false positive responses. It appears that educational programs developed for the mentally retarded need to be aware of the role of these deficits in the mentally retarded adult.

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